OSI Physical Layer

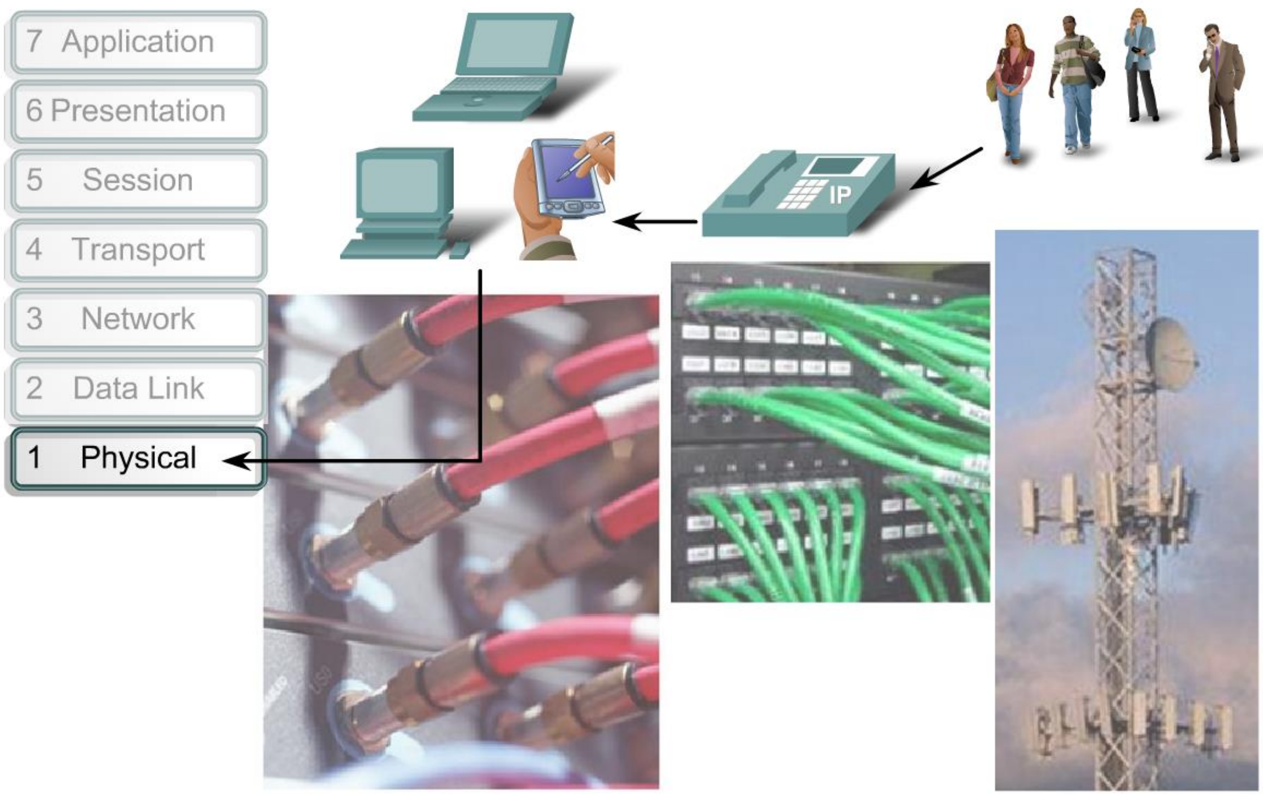
Lect. 3

Objectives

- Explain the role of Physical layer protocols and services in supporting communication across data networks.
  - Describe the role of signals used to represent bits as a frame as the frame is transported across the local media
- Describe the purpose of Physical layer signaling and encoding as they are used in networks
- Identify the basic characteristics of copper, fiber and wireless network media
- Describe common uses of copper, fiber and wireless network media

Physical Layer Protocols & Services

- Describe the purpose of the Physical layer in the network and identify the basic elements that enable this layer to fulfill its function



The Physical layer interconnects our data networks.

Physical Layer Protocols & Services

- The OSI Physical layer provides the means to transport across the network media the bits that make up a Data Link layer frame.
- The delivery of frames across the local media requires the following Physical layer elements:

  - The physical media and associated connectors

  - A representation of bits on the media

  - Encoding of data and control information

  -Transmitter and receiver circuitry on the network devices

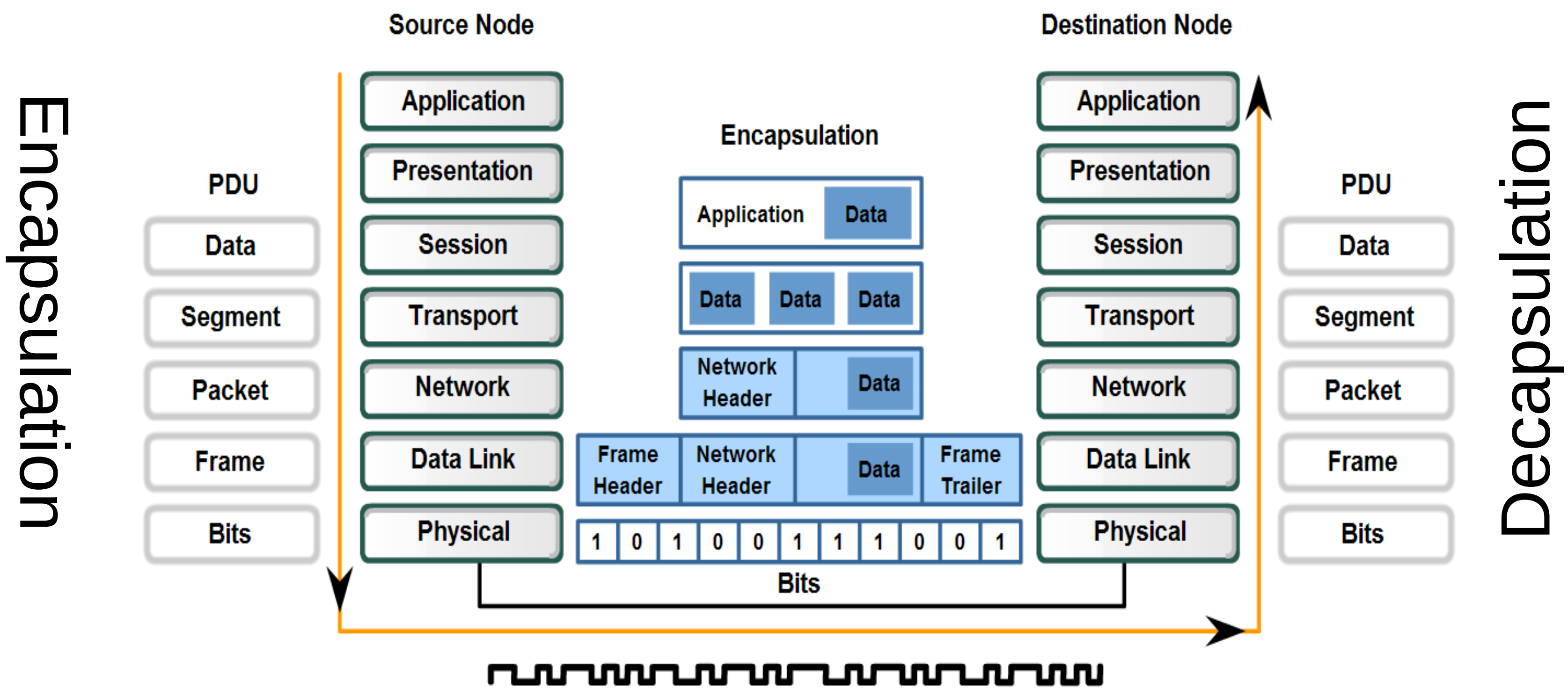
Physical Layer Protocols & Services

- The purpose of the Physical layer is to create the electrical, optical, or microwave signal that represents the bits in each frame.
- It is also the job of the Physical layer to retrieve these individual signals from the media, restore them to their bit representations, and pass the bits up to the Data Link layer as a complete frame.

Physical Layer Protocols & Services

- Describe the role of bits in representing a frame as it is transported across the local media.

Transforming Human Network Communications to Bits



Physical Layer Protocols & Services

- The media does not carry the frame as a single entity. The media carries signals, one at a time, to represent the bits that make up the frame.
- There are three basic forms of network media on which data is represented:

  - Copper cable

  - Fiber

  - Wireless

Physical Layer Protocols & Services

- The representation of the bits - that is, the type of signal - depends on the type of media.

  - copper cable media - patterns of electrical pulses.

  - fiber- patterns of light.

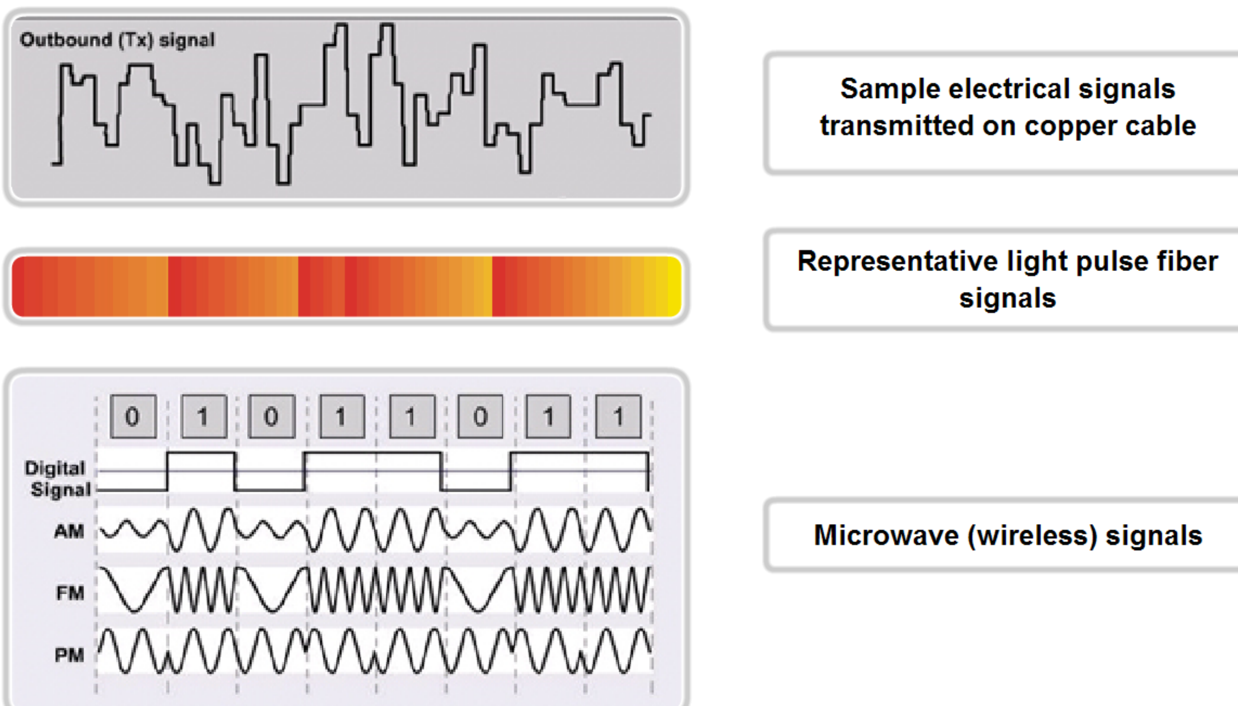
  - For wireless media - radio transmissions.

(See next slide)

Physical Layer Protocols & Services

- Describe the role of signaling in the physical media.

Representations of Signals on the Physical Media



Physical Layer Protocols & Services

- Modulation/Demodulation (modem)
- Multiplexing Schemes: Exploring how multiple conversations can be put on the same transmission medium at the same time without interfering with one another.

- Information must be transformed into signals before it can be transported across communication media.

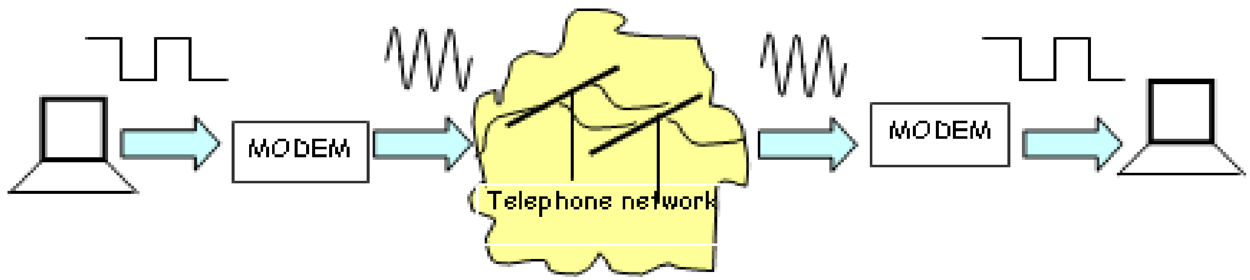
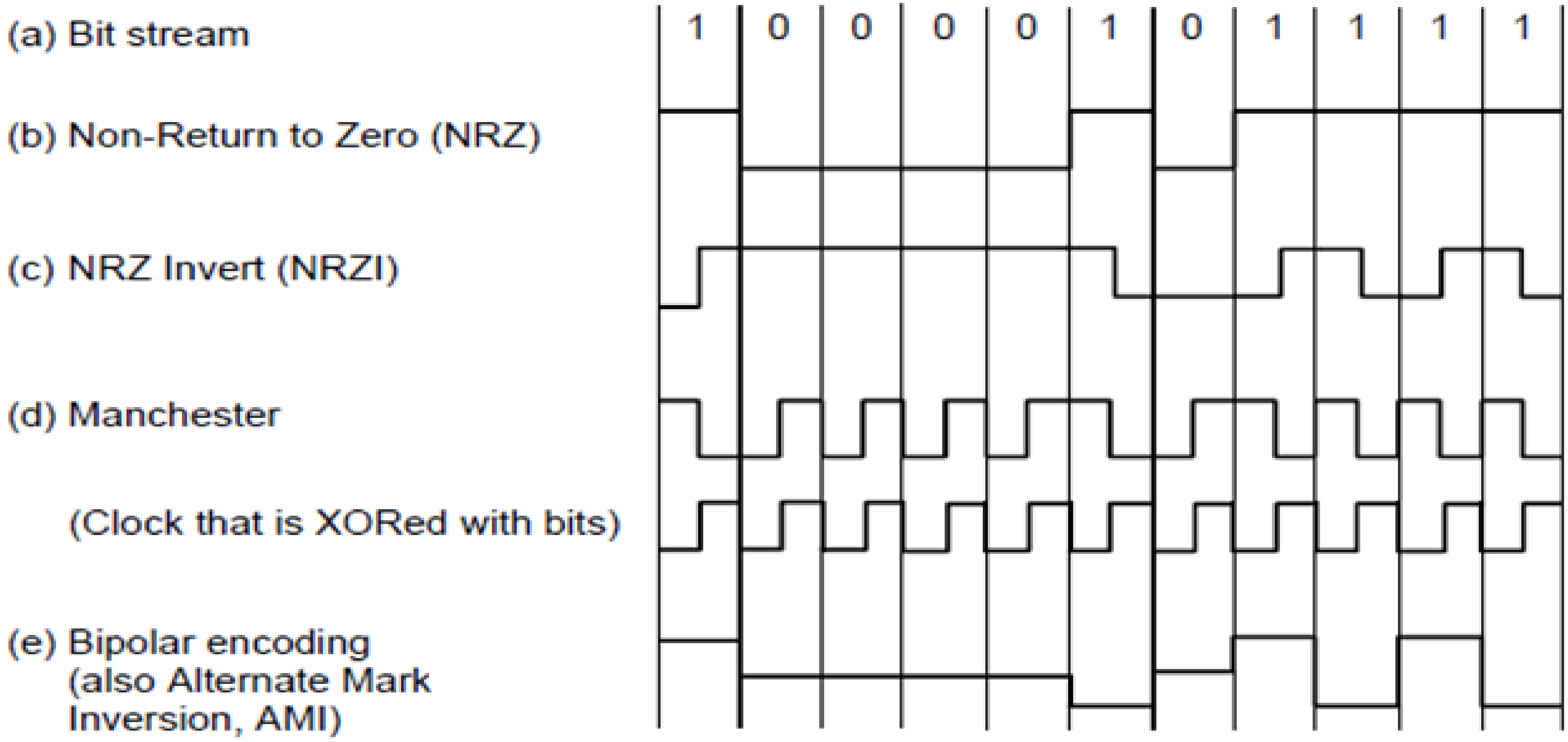


Fig. 2.1: Modem operation over a telephone network.

Digital Modulation and Multiplexing

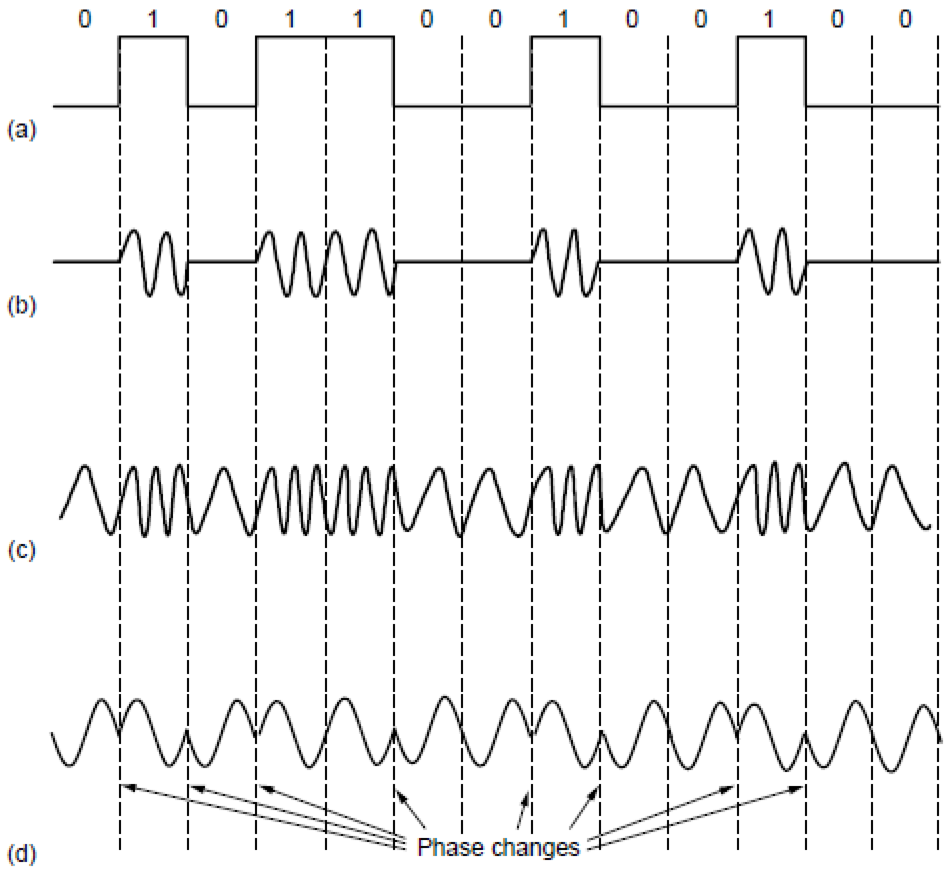
- Baseband Transmission
- Passband Transmission
- Frequency Division Multiplexing
- Time Division Multiplexing
- Code Division Multiplexing

Baseband Transmission



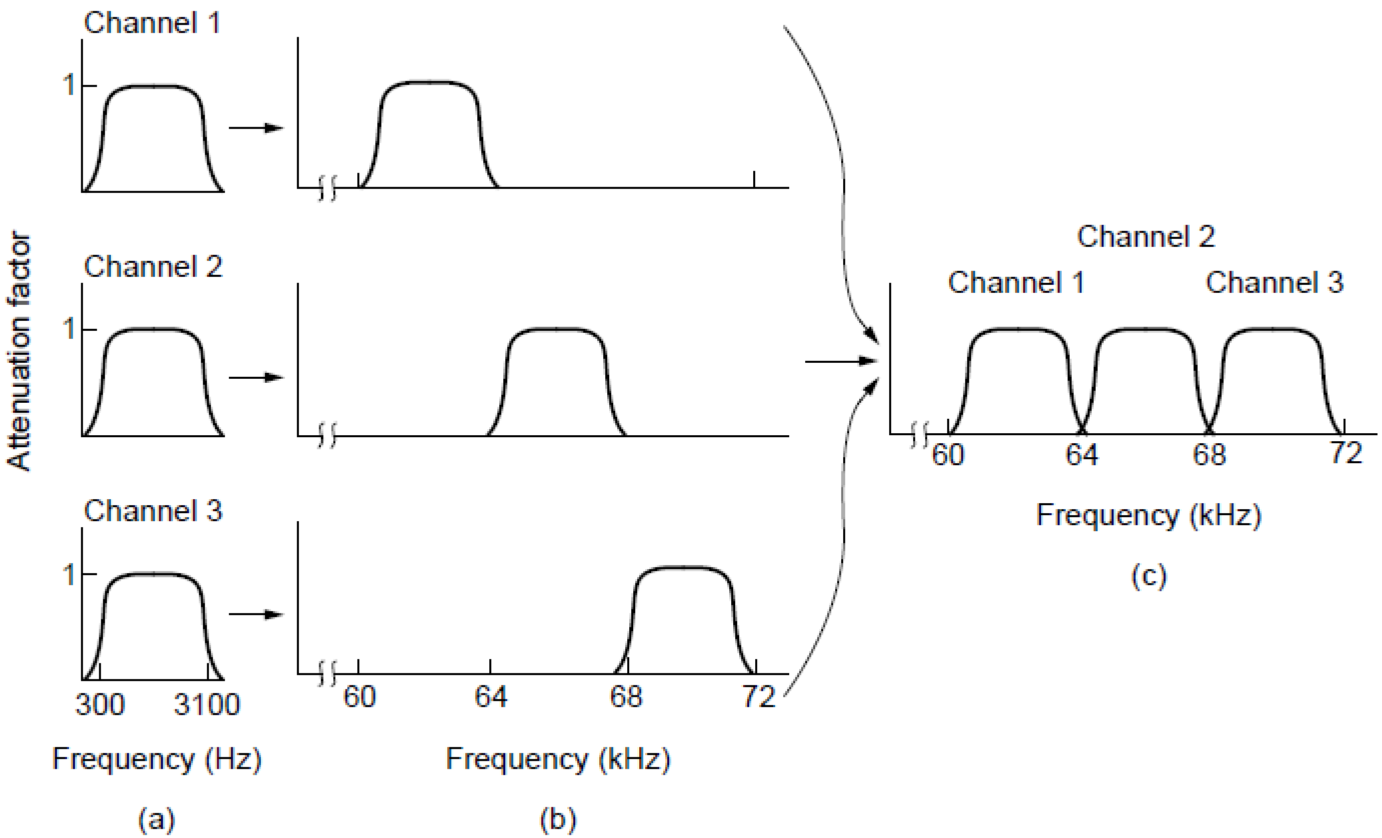
Line codes: (a) Bits, (b) NRZ, (c) NRZI,
(d) Manchester, (e) Bipolar or AMI.

Passband Transmission (1)



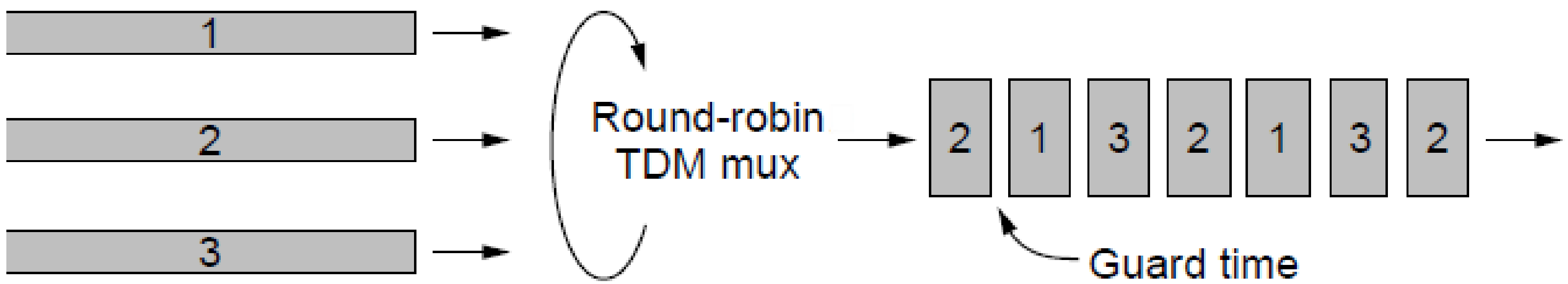
(a) A binary signal. (b) Amplitude shift keying.
(c) Frequency shift keying. (d) Phase shift keying.

Frequency Division Multiplexing (2)



Frequency division multiplexing. (a) The original bandwidths.
(b) The bandwidths raised in frequency.
(c) The multiplexed channel.

Time Division Multiplexing



Time Division Multiplexing (TDM).

Digital-to-digital encoding (Line encoding)

As in LANs or Ethernets

Fig. 2.2: Digital-to-digital encoding.

Encoding performance parameters

- Signal spectrum
- Signal synchronization capability
- Signal error detecting capability
- Signal interference and noise immunity
- Cost and complexity

Physical Layer Signaling and Encoding

- The Physical layer represents each of the bits in the frame as a signal.
- Each signal placed onto the media has a specific amount of time to occupy the media. This is referred to as its **bit time**.
- Successful delivery of the bits requires some method of synchronization between transmitter and receiver.
- The signals representing the bits must be examined at specific times during the bit time to properly determine if the signal represents a "1" or a "0".

Signaling Methods

- **Non-Return to Zero (NRZ),** a 0 may be represented by one voltage level on the media during the bit time and a 1 might be represented by a different voltage on the media during the bit time
- This simple method of signaling is only suited for slow speed data links. .
- The boundaries between individual bits can be lost when long strings of 1s or 0s are transmitted consecutively.

Non–return to zero (NRZ) codes

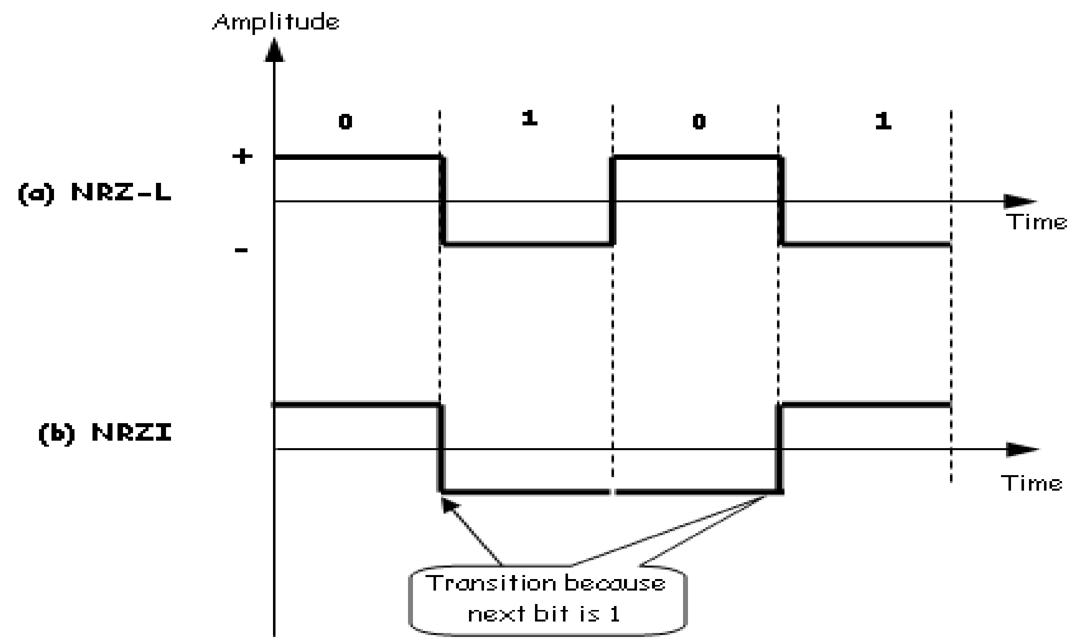


Fig. 2.3: Waveforms of NRZ-L and NRZI.

Advantages of NRZ schemes

•The NRZ is the easiest encoding scheme to be engineered.
•It makes an efficient use of bandwidth.

Limitations (disadvantages) of NRZ schemes

•The presence of the dc component. This prevents the use of ac coupling.
•The lack of synchronization capability, i.e., it is difficult to determine where each bit ends and another begins.

The Multi level binary codes

- Bipolar-AMI approach (Alternative Mark Inversion)

  a binary 0 is represented by no signal (i.e., level zero) and

  a binary 1 is represented by a positive or negative pulse. The binary 1 pulses must alternate in polarity.

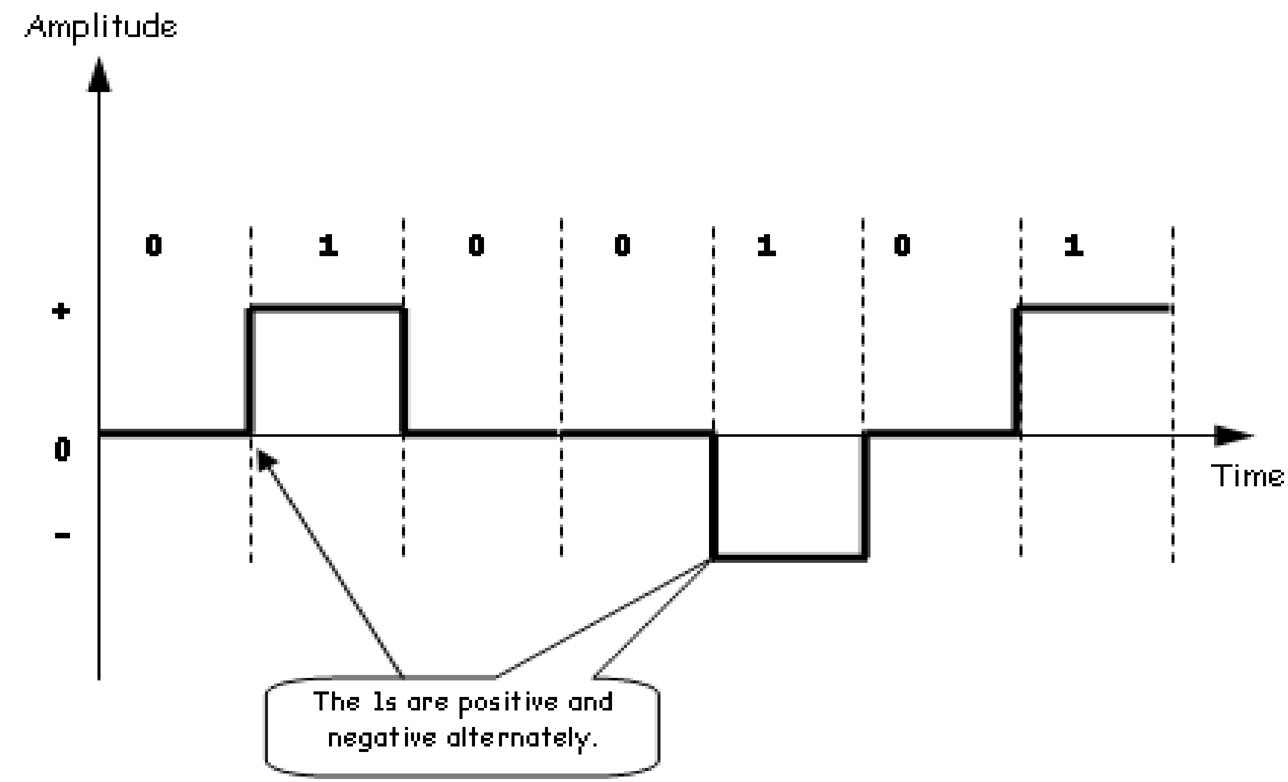


Fig. 2.4: The waveform of the Bipolar-AMI code.

The bi-phase codes (Return to Zero RZ)

- The Manchester Code

  a high–to–low transition represents a 1,

  a low–to–high transition represents a 0.

- Differential Manchester Code

  The encoding of a binary logic bit 0 is represented by the presence of a transition at the beginning of the bit period.

  The encoding of a binary logic 1 is represented by the absence of a transition at the beginning of the bit period.

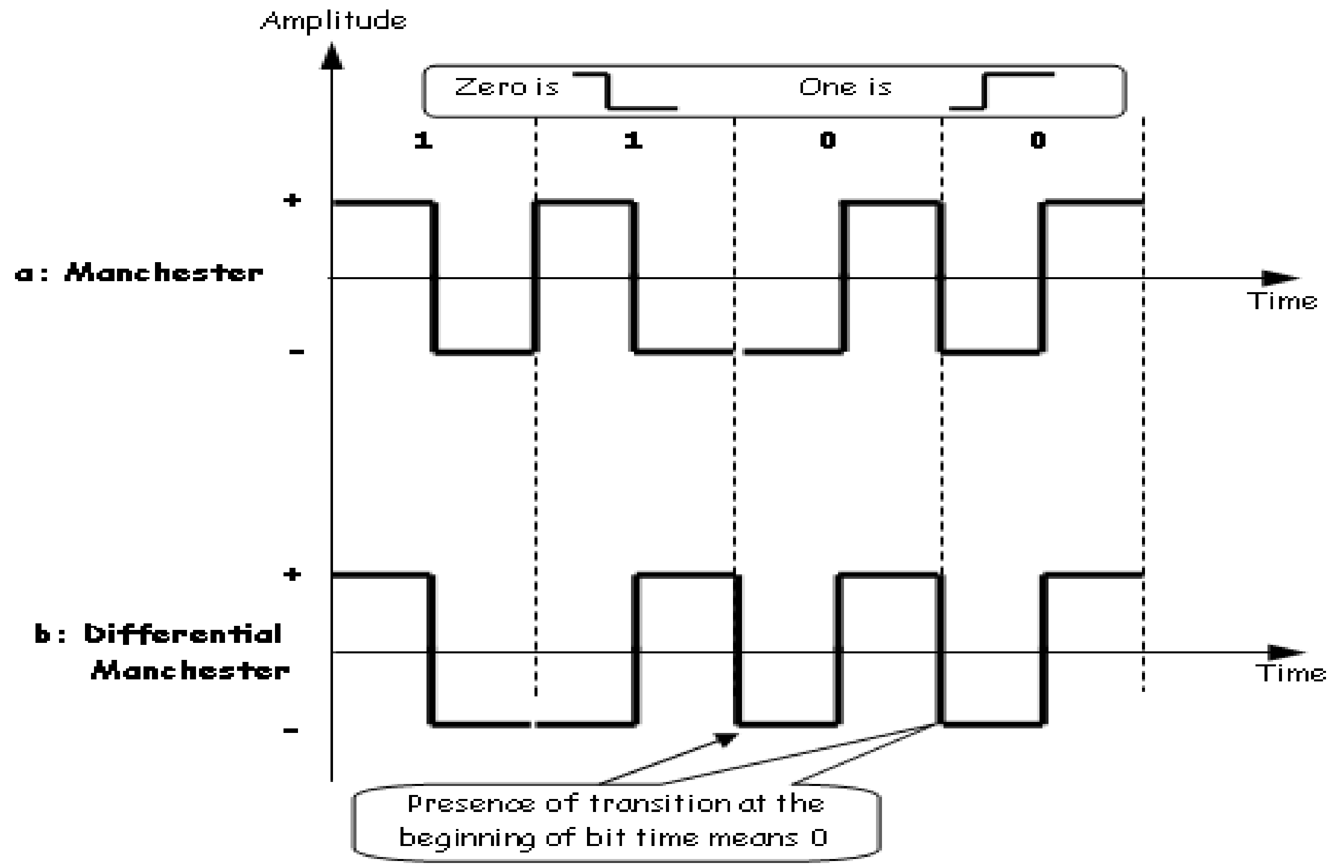
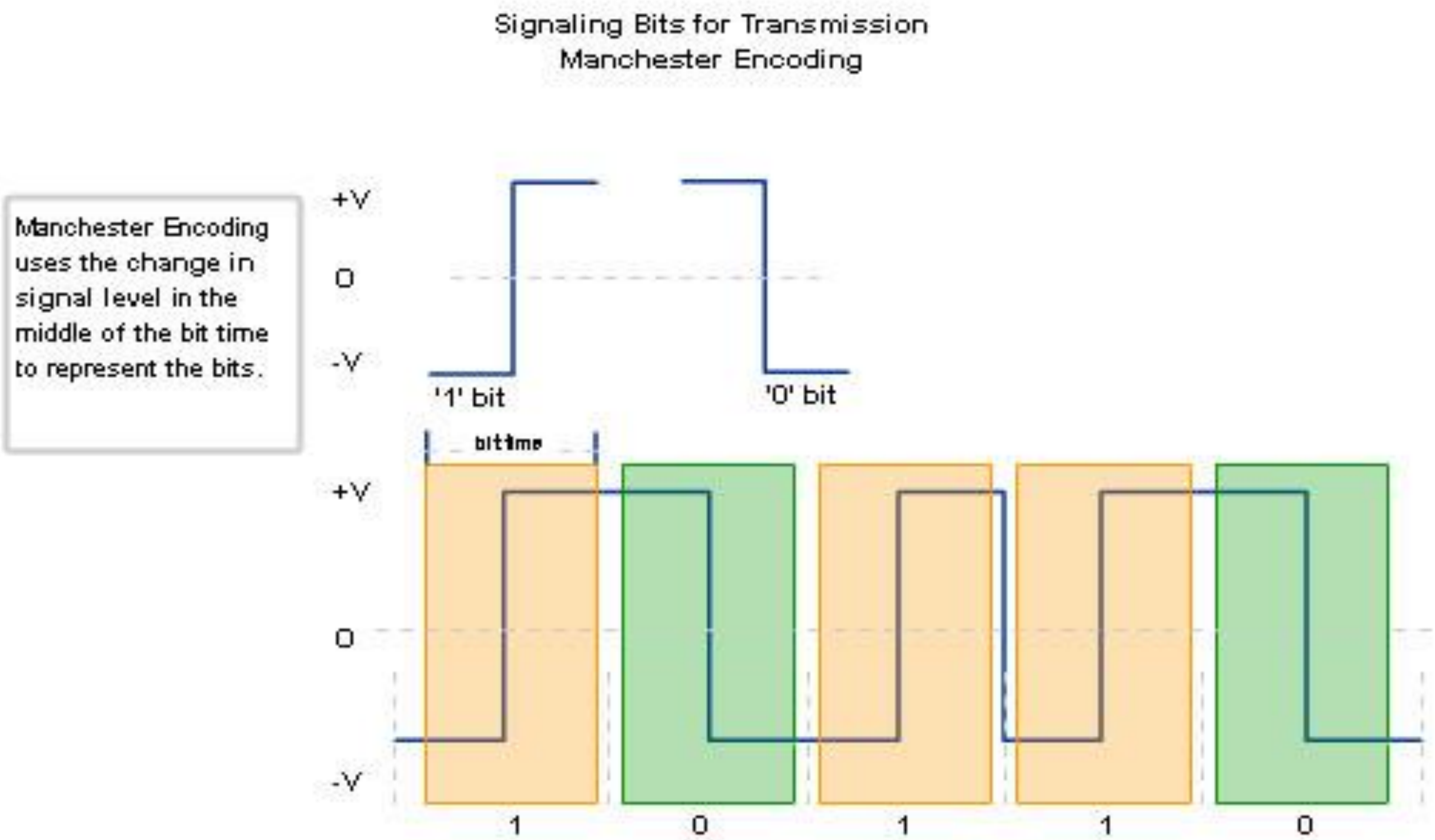


Fig. 2.5: Manchester and differential Manchester encoding.

Signaling Methods

- **Manchester Encoding** indicates a 0 by a high to low voltage transition in the middle of the bit time. For a 1 there is a low to high voltage transition in the middle of the bit time
- Although Manchester Encoding is not efficient enough to be used at higher signaling speeds, it is the signaling method employed by 10BaseT Ethernet (Ethernet running at 10 Megabits per second).



The signaling method used must be compatible with a standard so that the receiver can detect the signals and decode them.

Digital-to-Analog Encoding

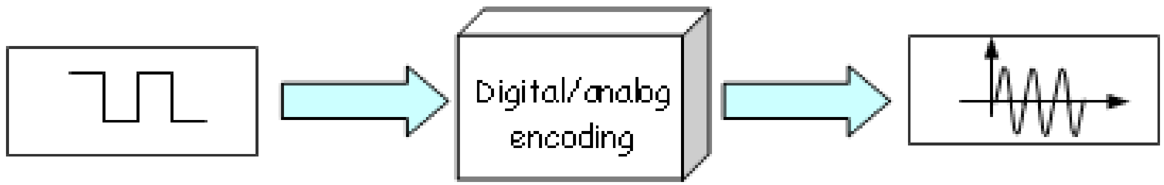


Fig. 2.7: Digital-to-analog modulation.

Amplitude Shift Keying (ASK)

$$S(t) = \begin{cases} A_1 \cos 2\pi f_c t & \text{for logic } 1 \\ A_2 \cos 2\pi f_c t & \text{for logic } 0 \end{cases}$$

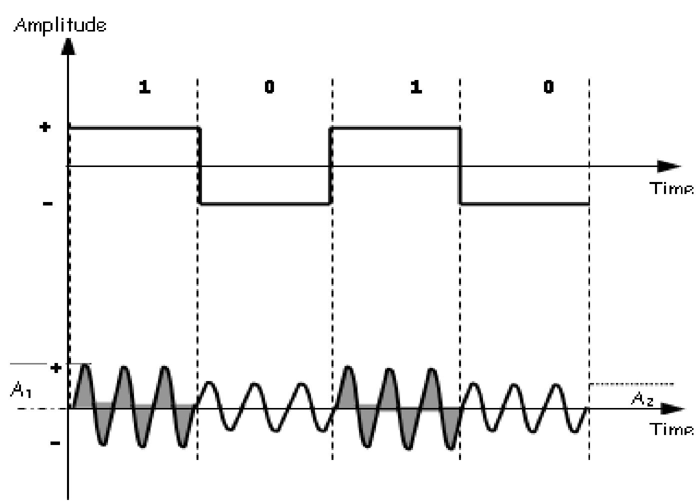


Fig. 2.8: Generation and waveform of ASK.

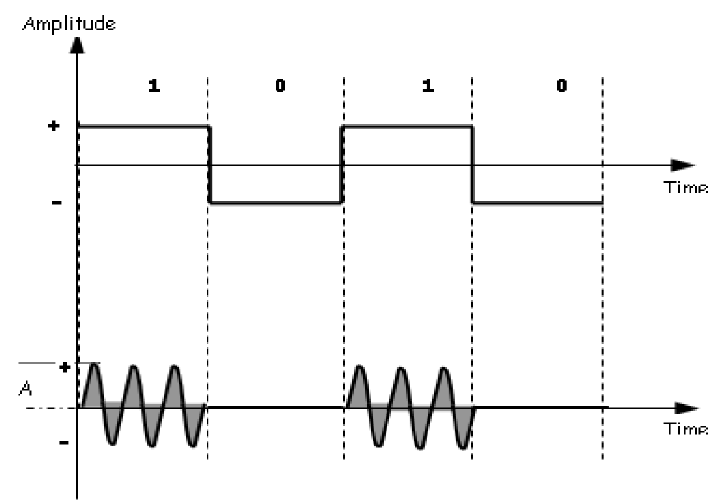


Fig. 2.9: Generation and waveform of OOK.

Frequency Shift Keying (FSK)

$$S(t) = \begin{cases} A\cos 2\pi f_1 t & \text{for logic } 1 \\ A\cos 2\pi f_2 t & \text{for logic } 0 \end{cases}$$

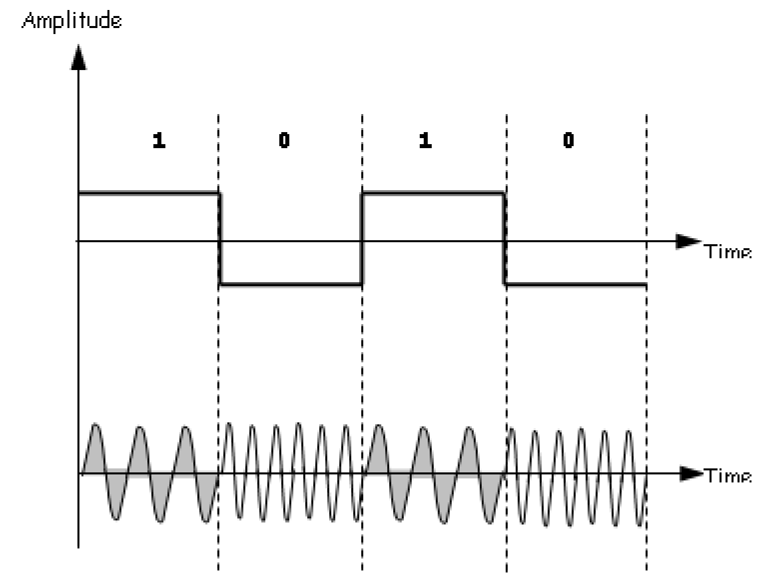


Fig. 2.11: The waveform of FSK.

Phase Shift Keying (PSK)

$$S(t) = \begin{cases} A\cos 2\pi f_c t + \pi & \text{for logic 1} \\ A\cos 2\pi f_c t & \text{for logic 0} \end{cases}$$

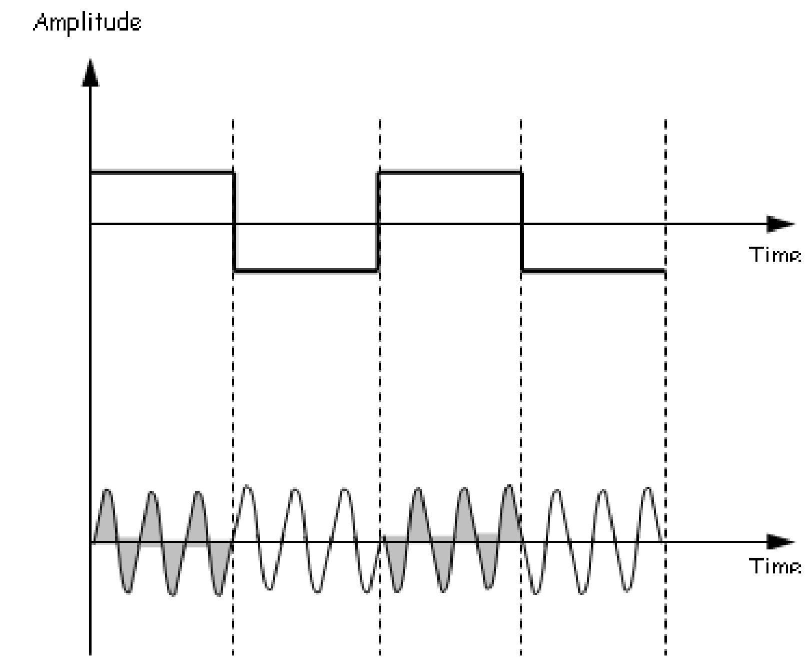


Fig. 2.12: The waveform of a differential PSK.

Physical Layer

Transmission Media

Transmission Media

Transmission medium:: the physical path between transmitter and receiver.

- Repeaters or amplifiers may be used to extend the length of the medium.
- Communication of electromagnetic waves is *guided* or *unguided.*

  Guided media :: waves are guided along a physical path (e.g, twisted pair, coaxial cable and optical fiber).

  Unguided media:: means for transmitting but not guiding electromagnetic waves (e.g., the atmosphere and outer space).

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Transmission Media Choices

- Twisted pair
- Coaxial cable
- Optical fiber
- Wireless communications

Data Carrying Capacity

- Different physical media support the transfer of bits at different speeds. Data transfer can be measured in three ways:
- Bandwith
- Throughput

Bandwidth

- Digital bandwidth measures the amount of information that can flow from one place to another in a given amount of time.
- The practical bandwidth of a network is determined by a combination of factors: the properties of the physical media and the technologies chosen for signaling and detecting network signals.
- Physical media properties, current technologies, and the laws of physics all play a role in determining available bandwidth.

Throughput

- Throughput is the measure of the successful transfer of bits across the media over a given period of time.
- Throughput usually does not match the specified bandwidth in Physical layer implementations such as Ethernet.
- Factors that influence throughput:
    - amount of traffic, the type of traffic, and the number of network devices encountered on the network being measured.

Characteristics & Uses of Network Media

- The most commonly used media for data communications is cabling that uses copper wires to signal data and control bits between network devices.
- Cabling used for data communications usually consists of a series of individual copper wires that form circuits dedicated to specific signaling purposes.
- The copper media type chosen is specified by the Physical layer standard required to link the Data Link layers of two or more network devices.
- Networking media generally make use of modular jacks and plugs, (Example: RJ 45: RJ = Registered Jack) which provide easy connection and disconnection. Also, a single type of physical connector may be used for multiple types of connections.

Type of Media – Copper Media

- Cables that use copper wires to signal data and control bits between network devices
- Ex: Twisted pair, Coaxial cable
- Data is transmitted on copper cables as electrical pulses.
- The timing and voltage values of these signals are susceptible to interference or "noise" from outside the communications system.
- Cable types with shielding or twisting of the pairs of wires are designed to minimize signal degradation due to electronic noise.

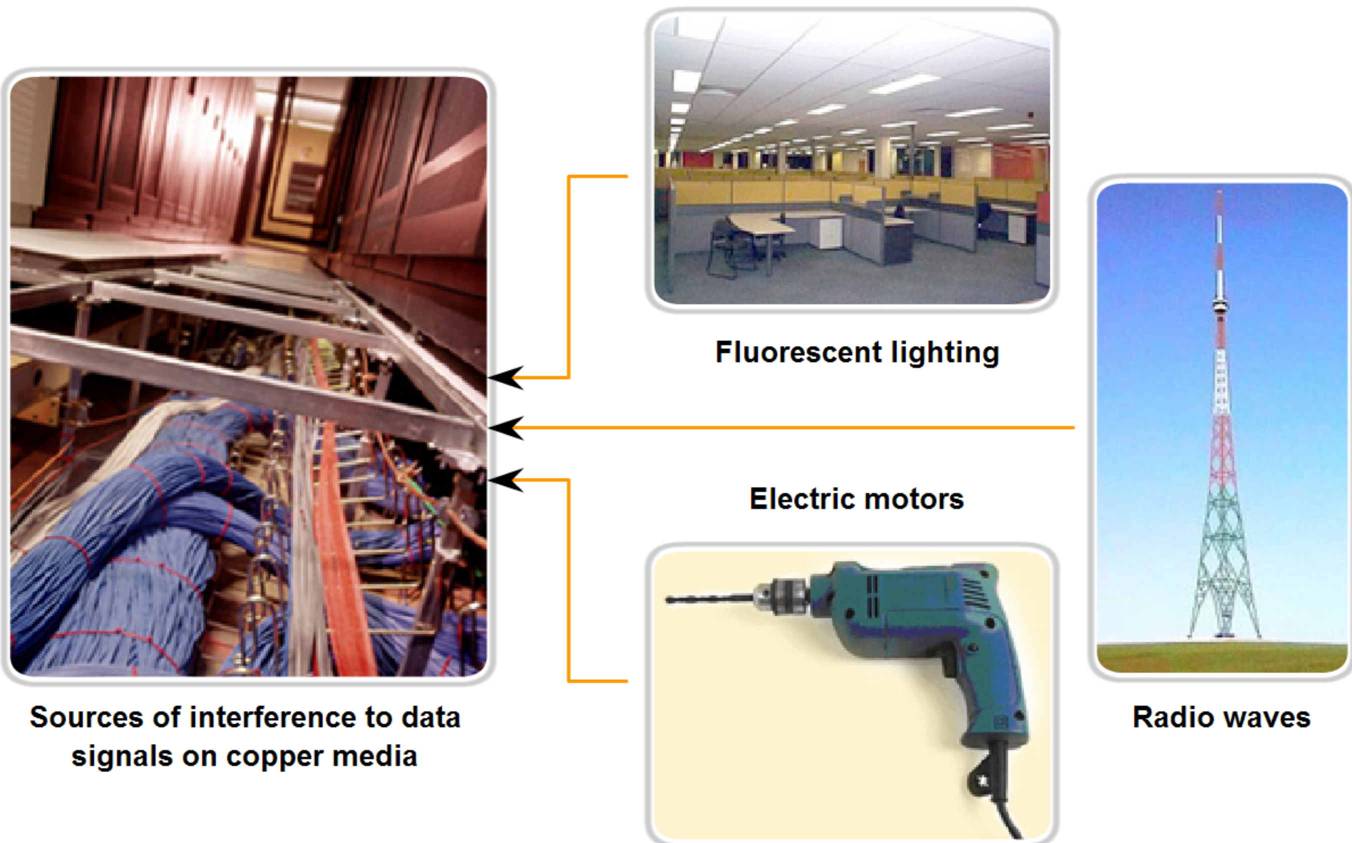
Type of Media – Copper Media

- The susceptibility of copper cables to electronic noise can also be limited by:
- Selecting the cable type or category most suited to protect the data signals in a given networking environment
- Designing a cable infrastructure to avoid known and potential sources of interference in the building structure
- Using cabling techniques that include the proper handling and termination of the cables

Characteristics & Uses of Network Media

- Describe the impact interference has on throughput and the role of proper cabling in reducing interference

External Interference with Copper Media



Twisted Pair

- Two insulated wires arranged in a spiral pattern
- Copper or steel coated with copper
- The signal is transmitted through one wire and a ground reference is transmitted in the other wire.
- Typically twisted pair is installed in building telephone wiring.
- Local loop connection to central telephone exchange is twisted pair.

Twisted Pair

- Limited in distance, bandwidth and data rate due to problems with attenuation, interference and noise

  Issue: cross-talk due to interference from other signals

  “shielding” wire (shielded twisted pair (STP)) with metallic braid or sheathing reduces interference.

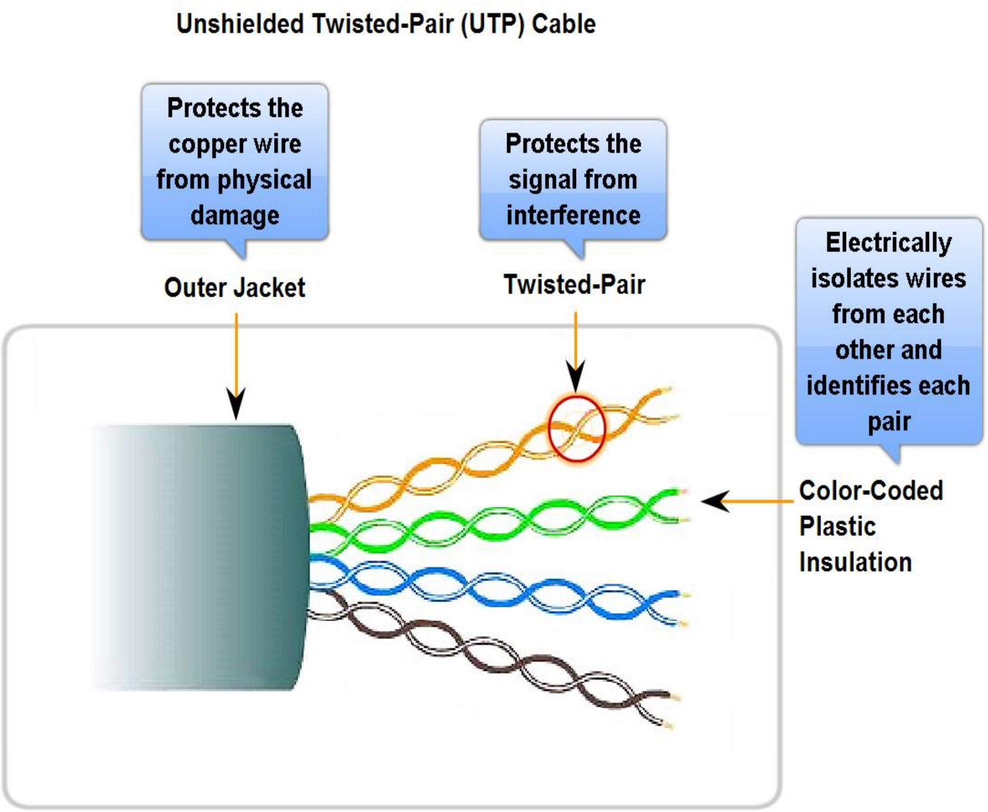
  “twisting” reduces low-frequency interference and crosstalk.

Type of Media – Copper Media - UTP

- UTP – Unshielded Twisted Pair
- Very common, cheap, easy to install
- It consists of 4 pairs of color-coded wires that have been twisted together
- The twisting has the effect of canceling unwanted signals.
- This cancellation effect also helps avoid interference from internal sources called crosstalk.
- Crosstalk is the interference caused by the magnetic field around the adjacent pairs of wires in the cable

Characteristics & Uses of Network Media

- Identify the basic characteristics of UTP cable



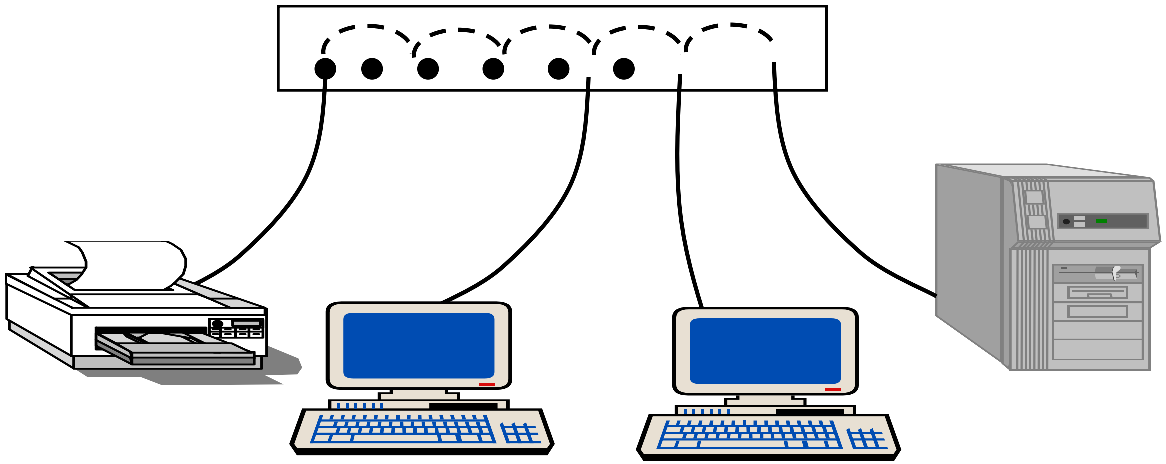
RJ-45 Connector

Type	Use
Category 1 (1Mhz)	Voice Only (Telephone Wire)
Category 2 (4Mhz)	Data to 4 Mbps (LocalTalk)
Category 3 (16Mhz)	Data to 10 Mbps (Ethernet)
Category 4 (20Mhz)	Data to 20 Mbps (16 Mbps Token Ring)
Category 5 (100Mhz)	Data to 100 Mbps (Fast Ethernet)
Category 5e (100Mhz)	Data to 1000Mbps (Full Duplex Fast Ethernet and Gigabit Ethernet)
Category 6 (250Mhz)	Data to 1000Mbps (more stringent specifications for crosstalk and system noise)

10BASE-T

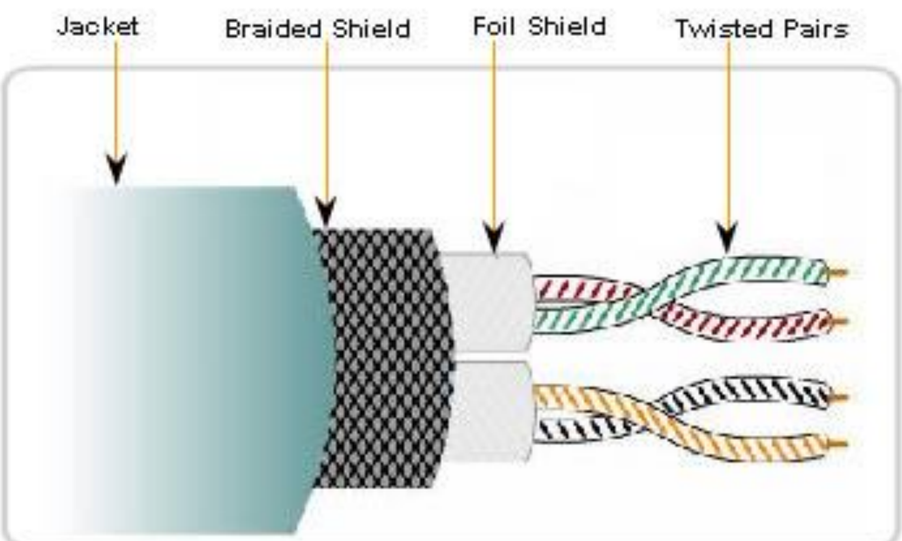
10 Mbps baseband transmission over *twisted pair*.
Two Cat 3 cables, Manchester encoding,
Maximum distance - 100 meters

Ethernet hub



Copper Media – Shielded Twisted Pair (STP)

- STP uses two pairs of wires that are wrapped in an overall metallic braid or foil.
- STP provides better noise protection than UTP cabling, however at a significantly higher price



UTP

Bad connector - Wires are untwisted for too great a length.

Good connector - Wires are untwisted to the extent necessary to attach the connector.

Coaxial Cable

- Discussion divided into two basic categories for coax used in LANs:
  - 50-ohm cable [baseband]
  - 75-ohm cable [broadband or single channel baseband]
- In general, coax has better noise immunity for higher frequencies than twisted pair.
- Coaxial cable provides much higher bandwidth than twisted pair.
- However, cable is ‘bulky’.

Baseband Coax

- 50-ohm cable is used exclusively for digital transmissions
- Uses Manchester encoding, geographical limit is a few kilometers.

10Base5 *Thick Ethernet* :: thick (10 mm) coax

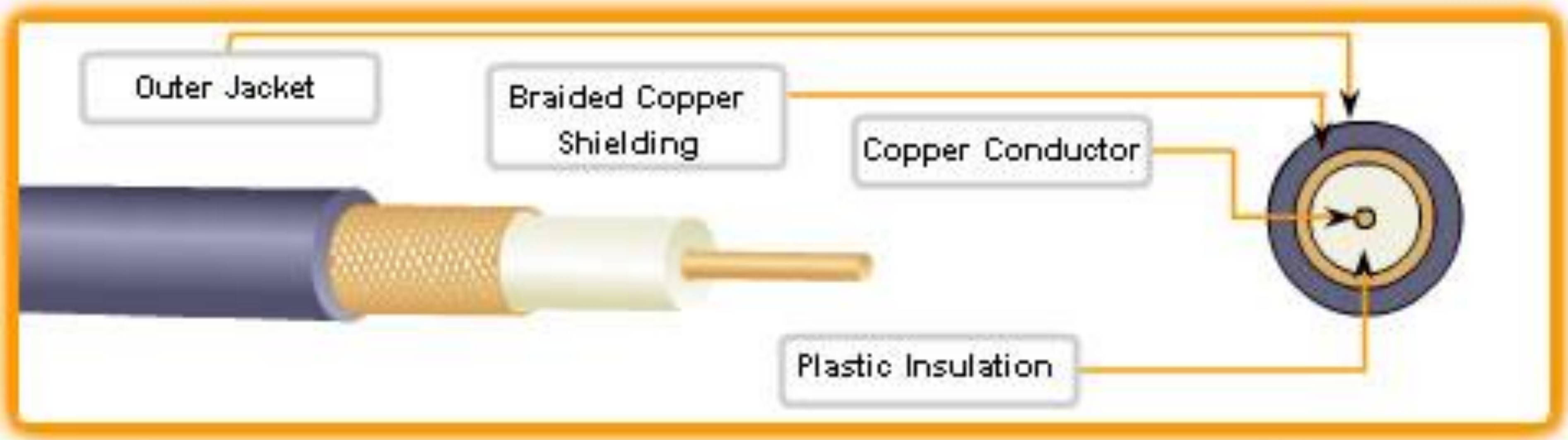
10 Mbps, 500 m. max segment length, 100 devices/segment, awkward to handle and install.

10Base2 *Thin Ethernet* :: thin (5 mm) coax

10 Mbps, 185 m. max segment length, 30 devices/segment, easier to handle, uses T-shaped connectors.

Broadband Coax

- 75-ohm cable (CATV system standard)
- Used for both analog and digital signaling.
- Analog signaling – frequencies up to 500 MHZ are possible.
- When FDM used, referred to as *broadband.*
- For long-distance transmission of analog signals, amplifiers are needed every few kilometers.


Outer Jacket
Braided Copper Shielding
Copper Conductor
Plastic Insulation


Coaxial Connectors
BNC
N type
F type

Fiber Media

- Fiber-optic cabling uses either glass or plastic fibers to guide light impulses from source to destination.
- The bits are encoded on the fiber as light impulses .
- Optical fiber cabling is capable of very large raw data bandwidth rates.
- Most current transmission standards have yet to approach the potential bandwidth of this media.

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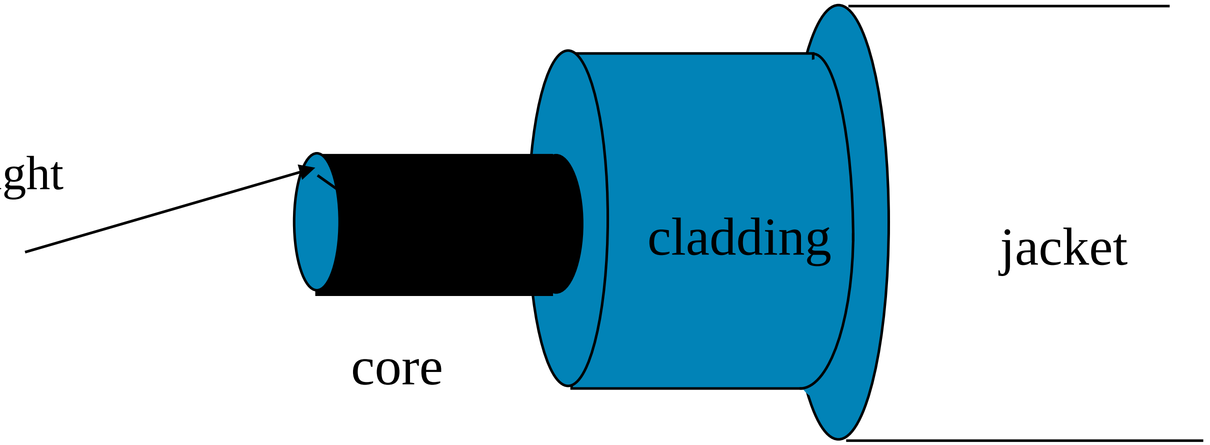
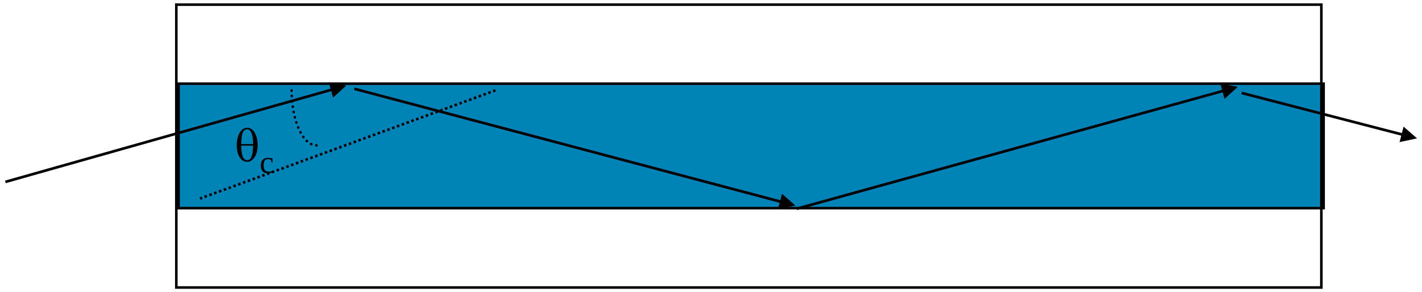
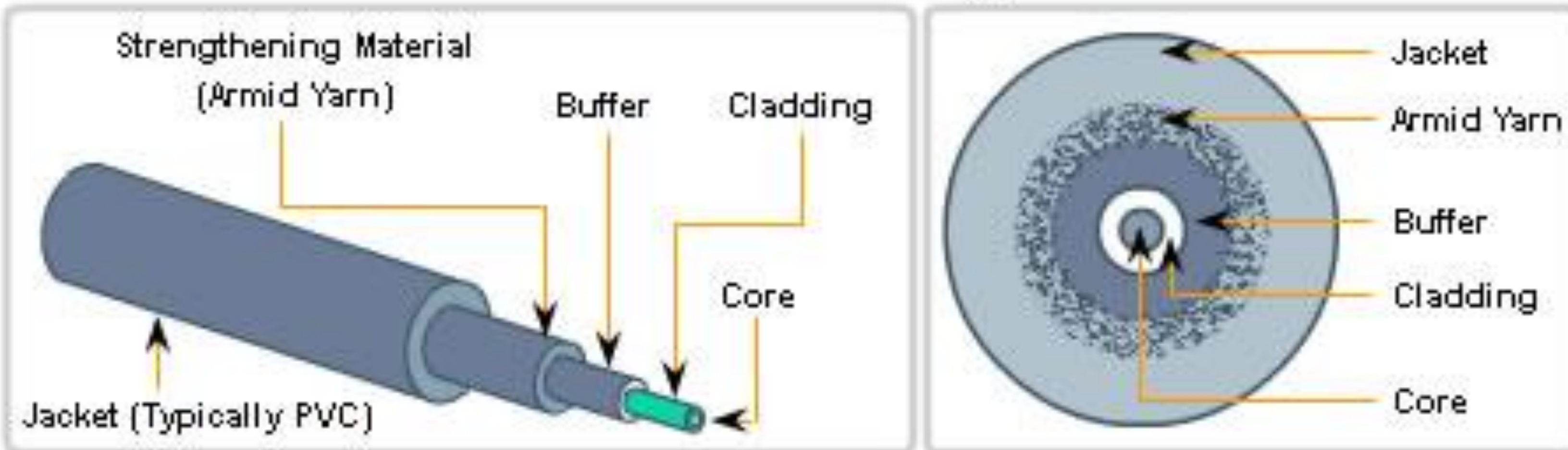
Optical Fiber

(a) Geometry of optical fiber



(b) Reflection in optical fiber





SECTION Rollover to change perspective.

Fiber Connectors

Media Connector – for fiber optics

ST Connector

Straight Tip (ST) connector is used with single-mode fiber

SC Connector

Subscriber Connector (SC) is used with multimode fiber

Single-Mode (LC)

Single-Mode Lucent Connector (LC)

Multi mode (LC)

Multimode LC Connector

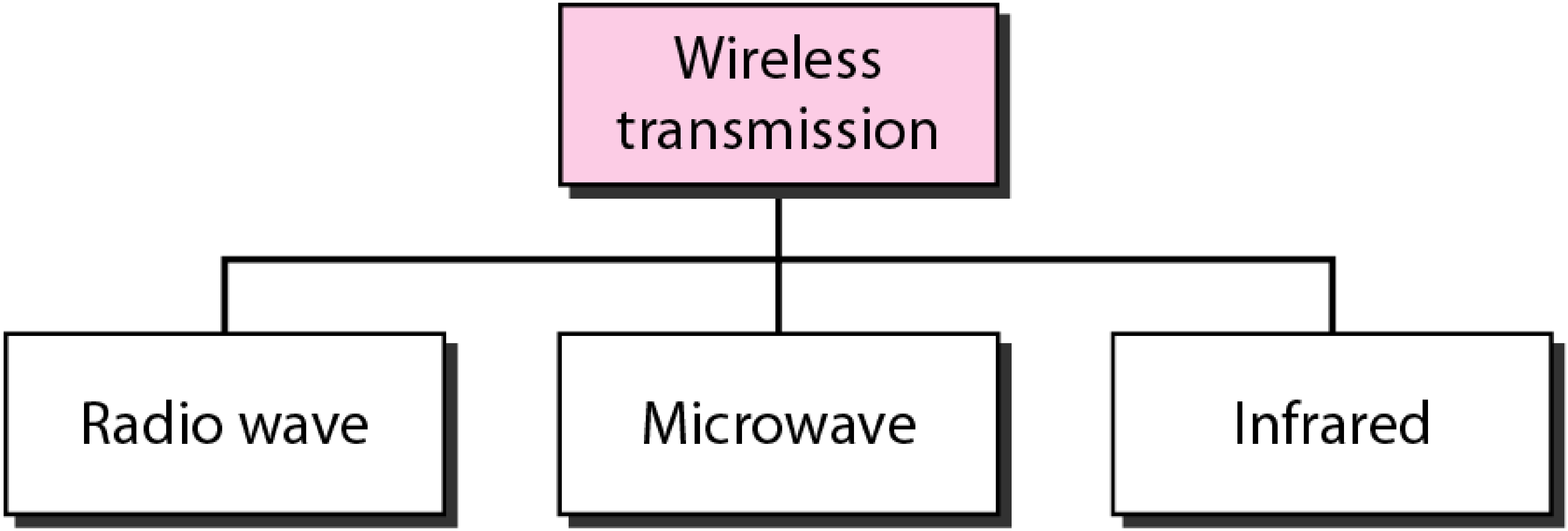
Duplex Multi mode (LC)

Duplex Multimode LC Connector

Fiber Compared to Copper Cabling

- Fiber media is immune to electromagnetic interference
- Optical fibers are thin and have relatively low signal loss, they can be operated at much greater lengths than copper media,
- More expensive (usually) than copper media over the same distance (but for a higher capacity)
- Different skills and equipment required to terminate and splice the cable infrastructure
- More careful handling than copper media

Wireless transmission waves



Electromagnetic spectrum for wireless communication

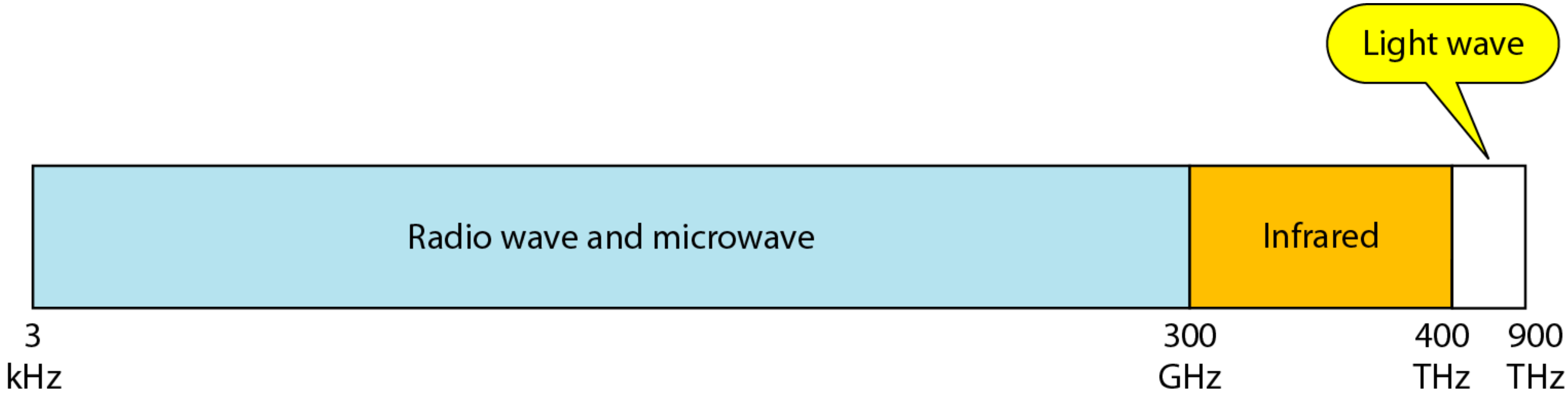


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Table 7.4 *Bands*

Band	*Range*	*Propagation*	*Application*
VLF (very low frequency)	3–30 kHz	Ground	Long-range radio navigation
LF (low frequency)	30–300 kHz	Ground	Radio beacons and navigational locators
MF (middle frequency)	300 kHz–3 MHz	Sky	AM radio
HF (high frequency)	3–30 MHz	Sky	Citizens band (CB), ship/aircraft communication
VHF (very high frequency)	30–300 MHz	Sky and line-of-sight	VHF TV, FM radio
UHF (ultrahigh frequency)	300 MHz–3 GHz	Line-of-sight	UHF TV, cellular phones, paging, satellite
SHF (superhigh frequency)	3–30 GHz	Line-of-sight	Satellite communication
EHF (extremely high frequency)	30–300 GHz	Line-of-sight	Radar, satellite

Note

Radio waves are used for multicast communications, such as radio and television. They can penetrate through walls. Highly regulated. Use omni directional antennas

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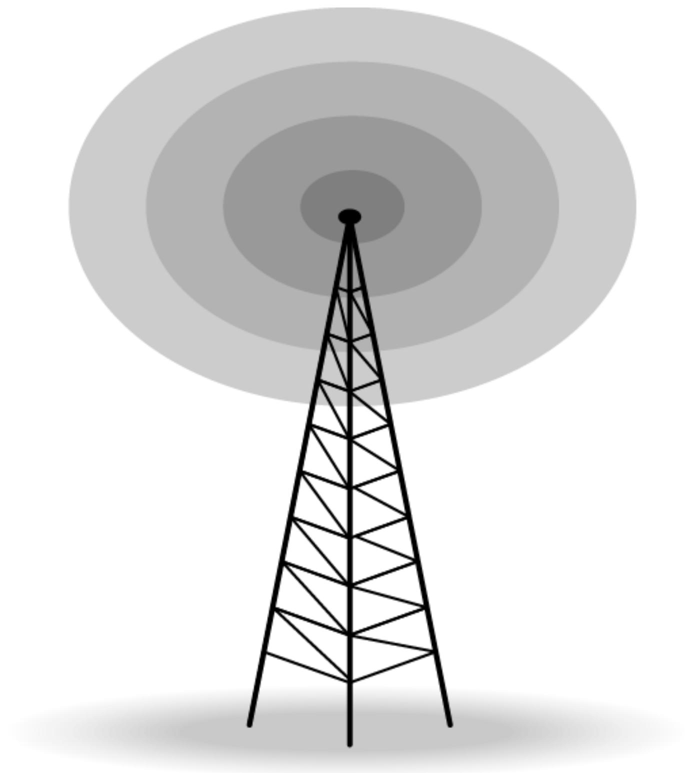
Omnidirectional antenna



Note

Microwaves are used for unicast communication such as cellular telephones, satellite networks,
and wireless LANs.
Higher frequency ranges cannot penetrate walls.
Use directional antennas - point to point line of sight communications.

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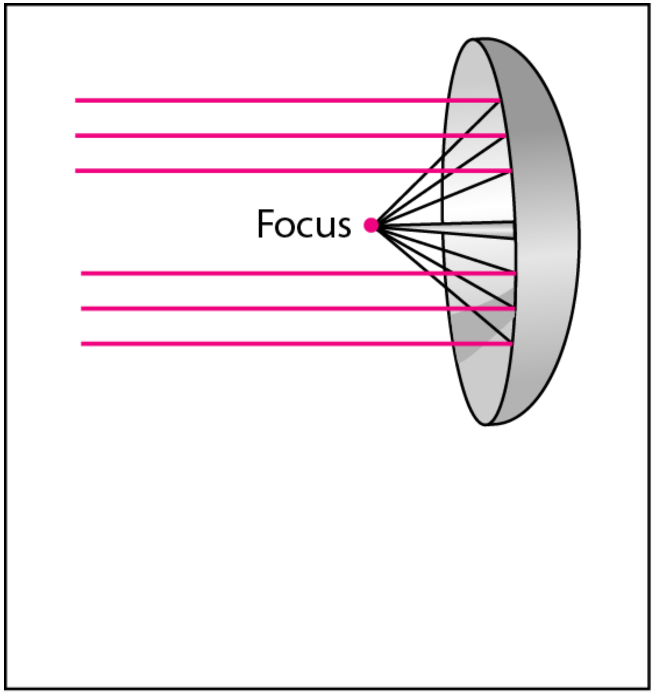
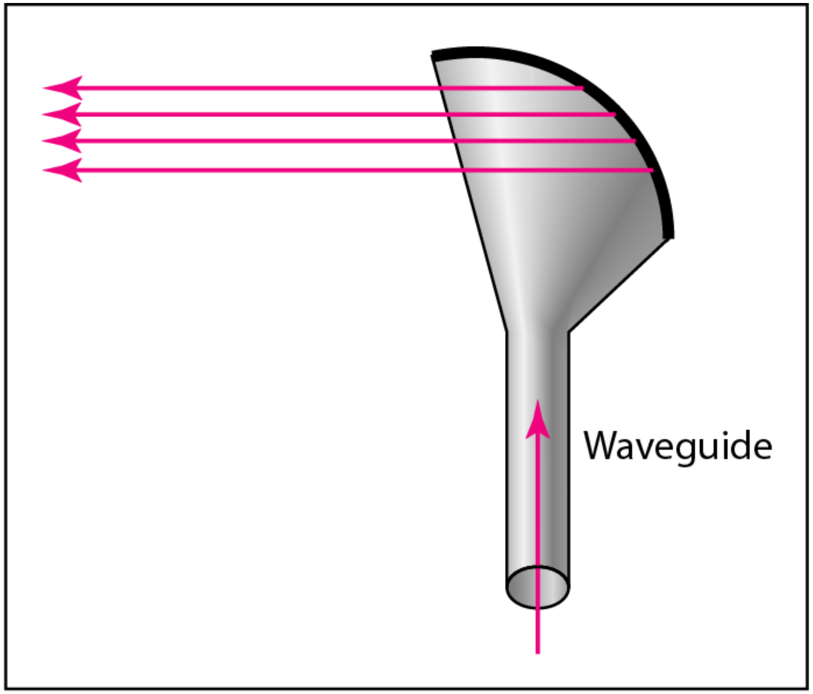
Unidirectional antennas



a. Dish antenna



b. Horn antenna

Note

Infrared signals can be used for short-range communication in a closed area using line-of-sight propagation.

Wireless Channels

- Are subject to a lot more errors than guided media channels.
- Interference is one cause for errors, can be circumvented with high SNR.
- The higher the SNR the less capacity is available for transmission due to the broadcast nature of the channel.
- Channel also subject to fading and no coverage holes.